The Dynamical Implications of Changes in mid-Stratospheric Ozone since 1991

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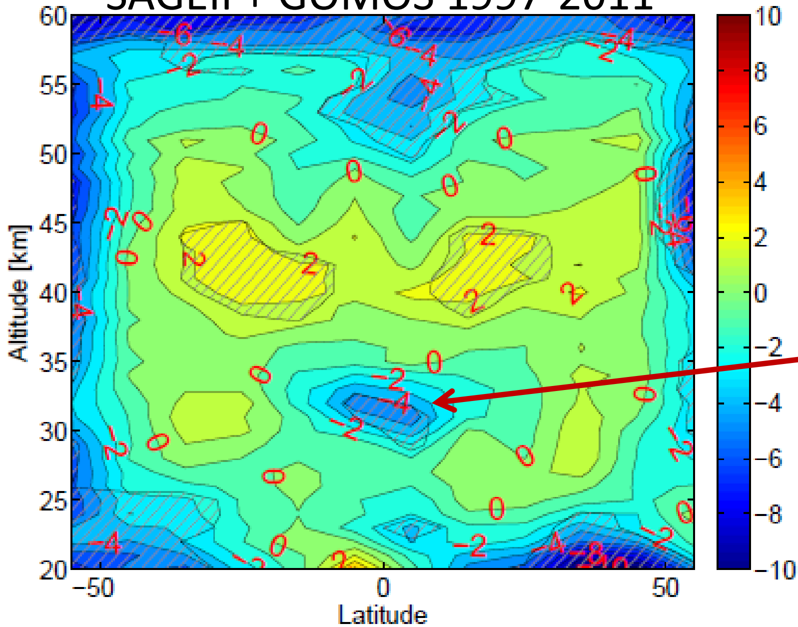
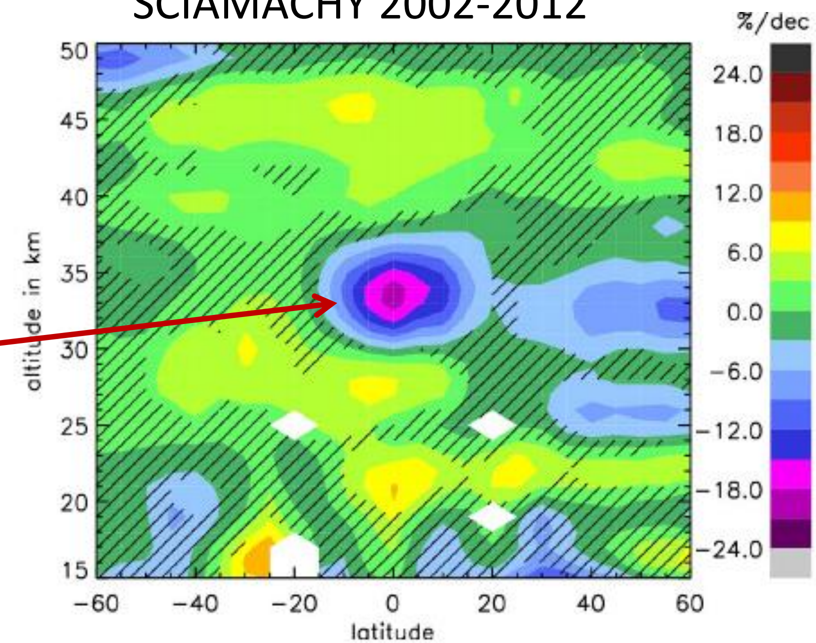
Published O_3 trends

SAGEII + GOMOS 1997-2011



%/decade

SCIAMACHY 2002-2012



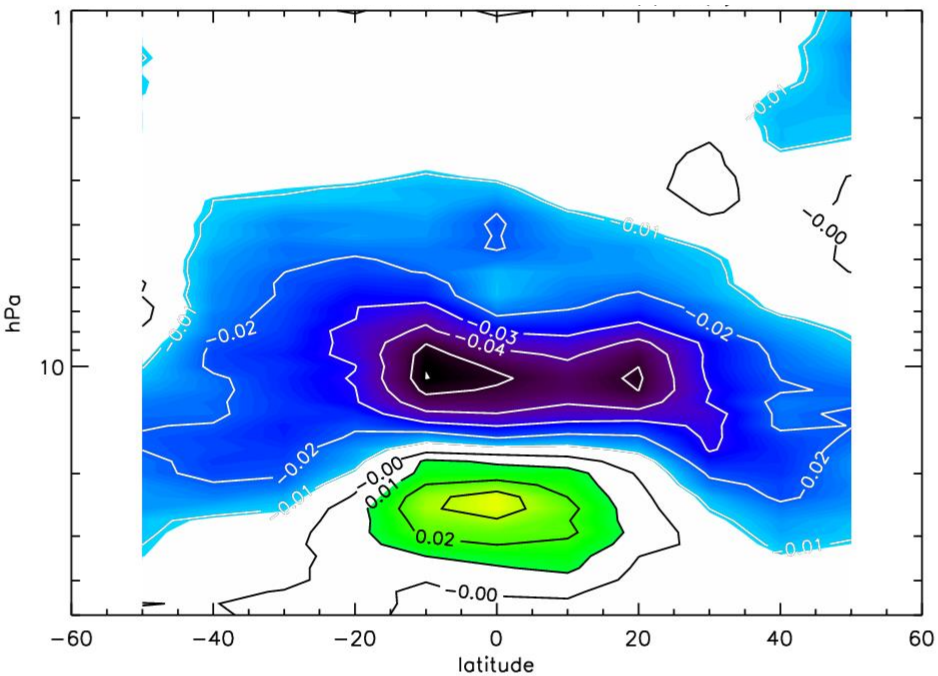
Kyrola et al.,
ACP 2013

Gebhardt et al.,
ACP 2014

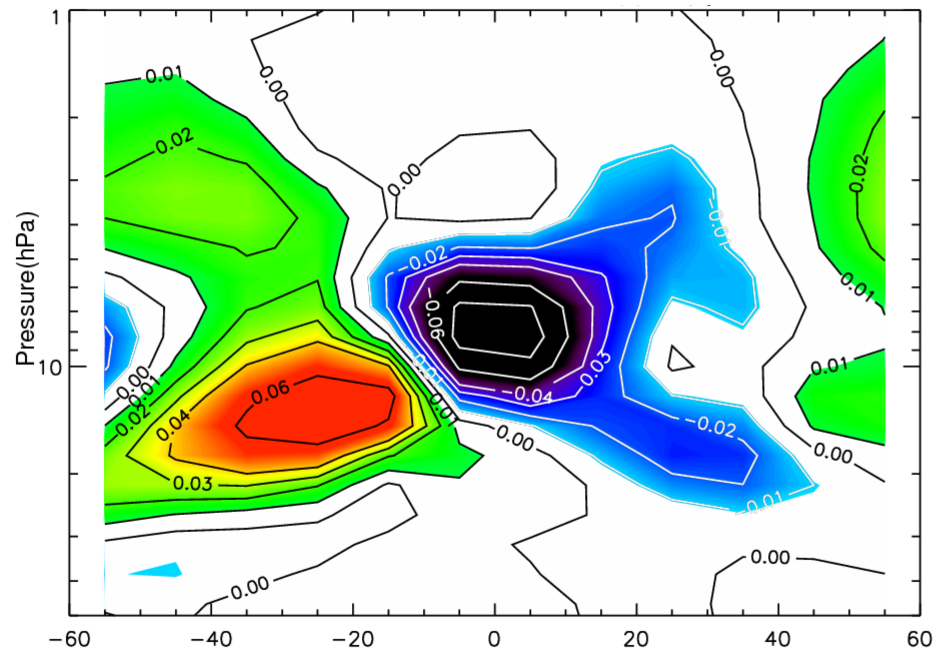
O_3 recovery in upper stratosphere

Large long-term O_3 decrease near 30km in tropics

HALOE O_3 trend 1991-2005 (ppmv/yr)



MLS O_3 trend 2004-2013 (ppmv/yr)



Peak observed O_3 trends (~10 hPa):

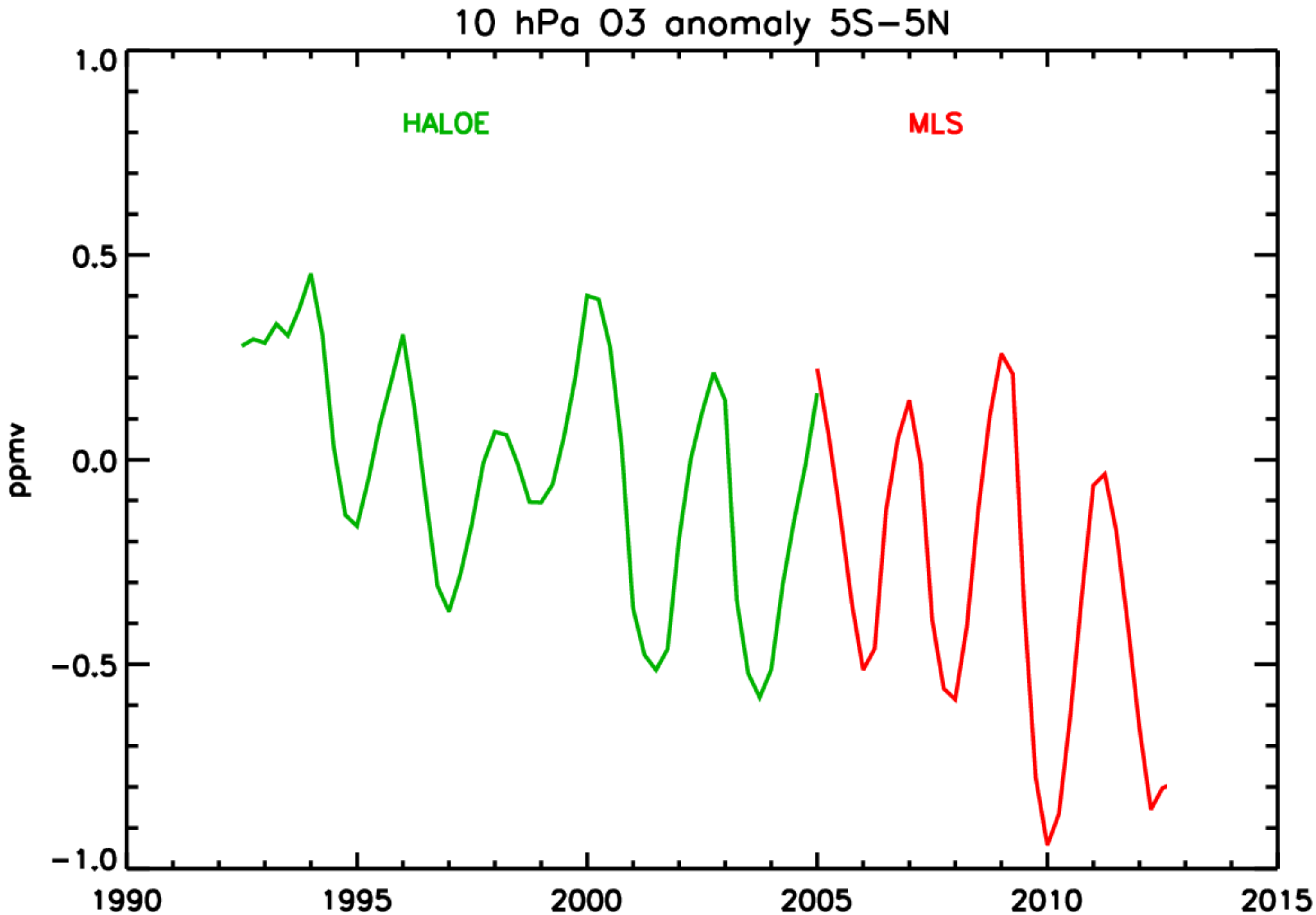
~60 ppbv/yr for HALOE

~100 ppbv/yr for MLS

Some emission scenario calculations:

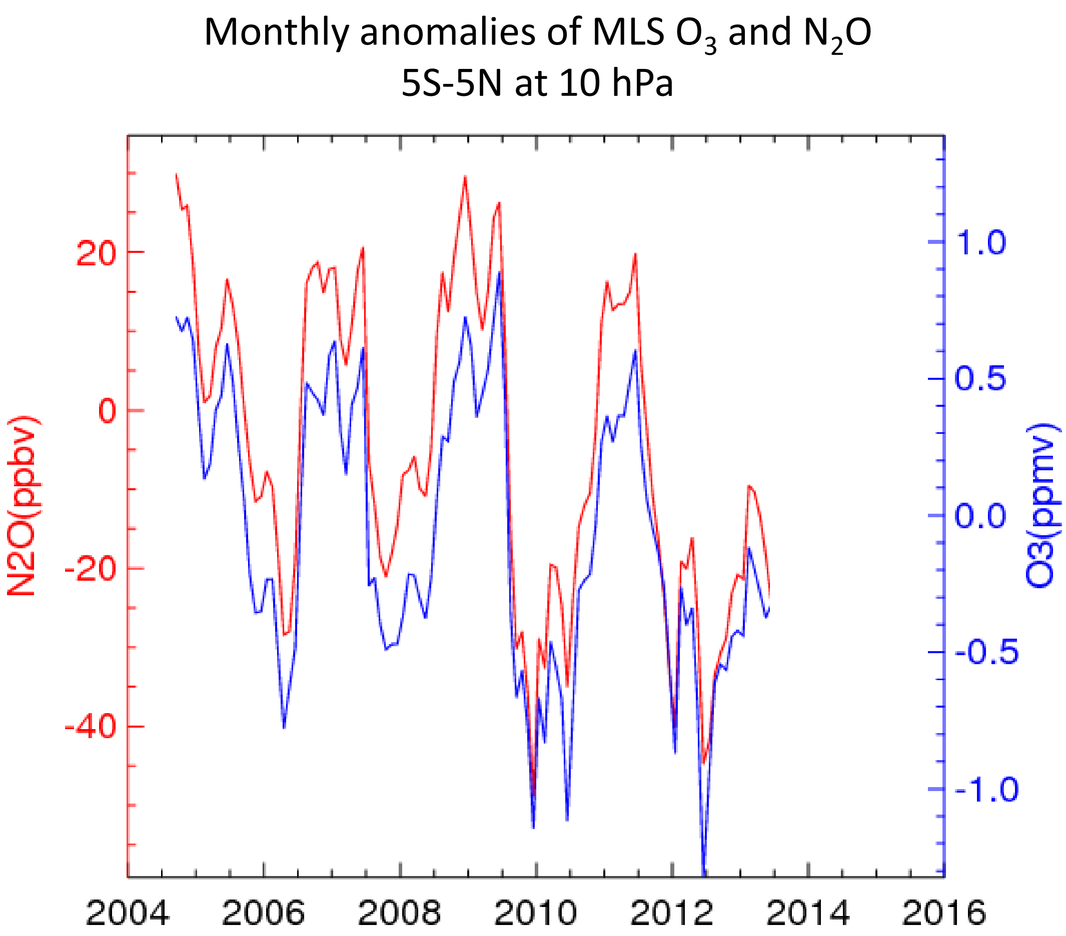
20 ppbv increase in surface N_2O over 20 year (IPCC A1B) => 5-7ppbv/yr decrease in O_3

Portmann et al., 2012



Annual average anomalies shown 4-times per year.
MLS is shifted to match up with HALOE during overlap period.
Decrease seems unrelated to solar cycle.

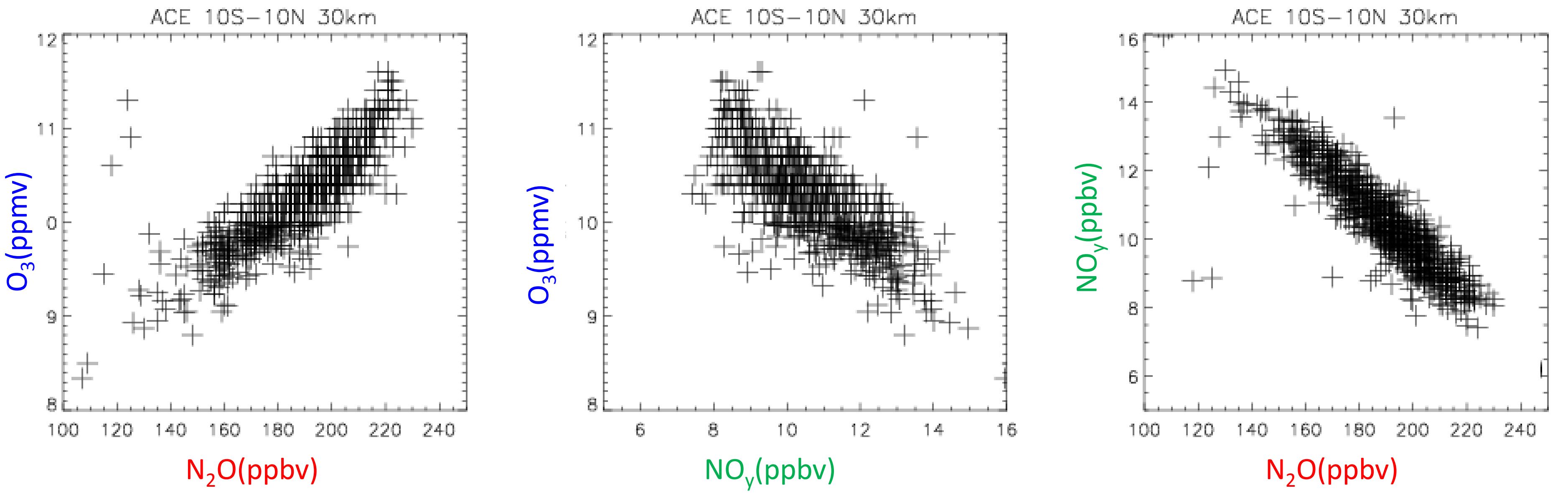
The *Positive* Correlation Between O_3 and N_2O



Understanding the relationship between N_2O and O_3

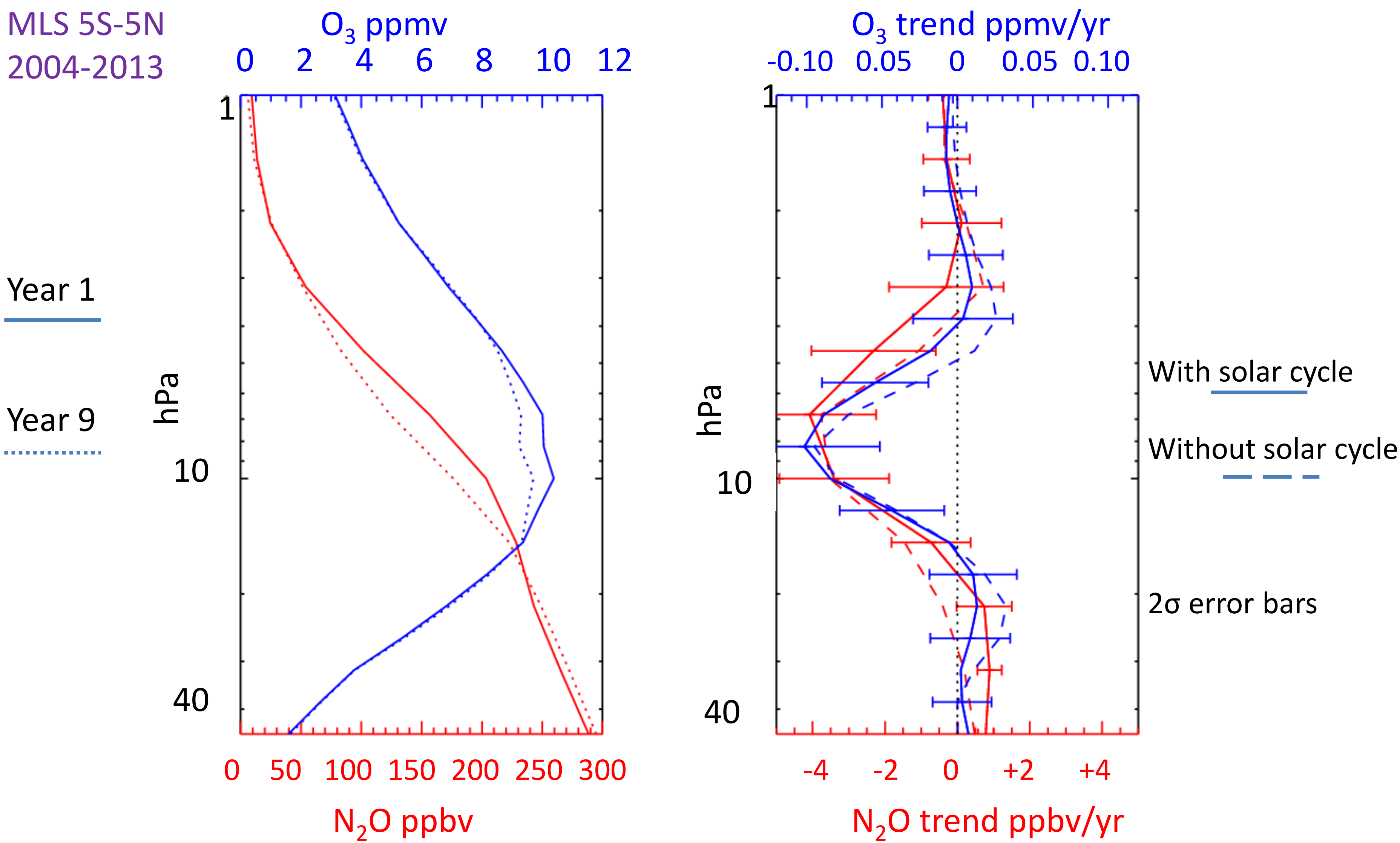
ACE-FTS measurements
10S-10N 30km

O_3
N_2O
$NO_y = NO+NO_2+HNO_3+2*N_2O_5$
ACE sunrise and sunset measurements are both shown here



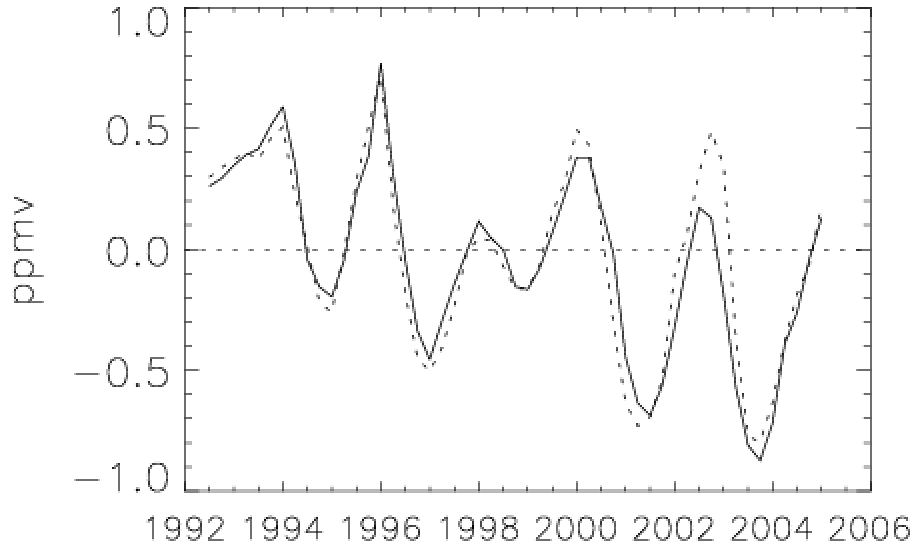
N_2O anti-correlates with NO_y
NO_y anti-correlates with O_3
→ N_2O correlates with O_3

Vertical profiles of tropical O_3 and N_2O changes from linear trends



HALOE timeseries 5S-5N, 10 hPa

HALOE O_3



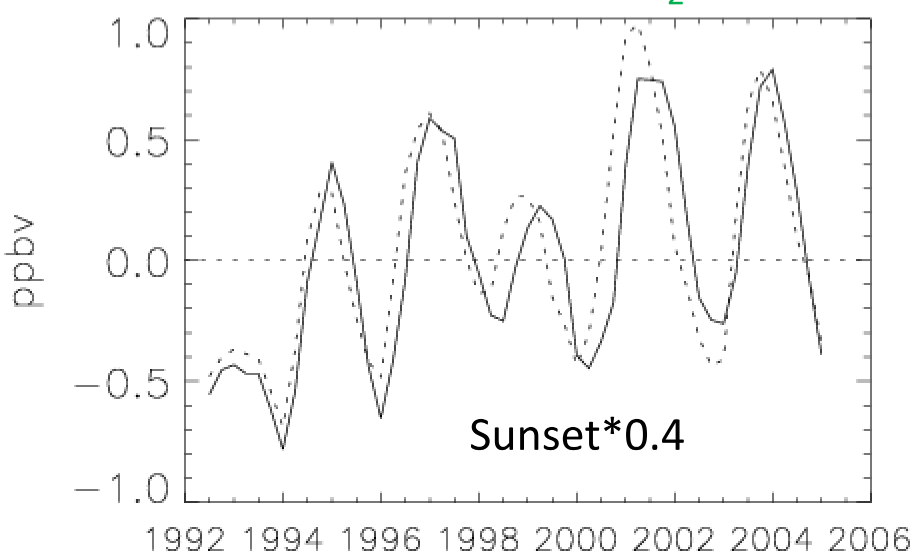
HALOE does not provide N_2O, but it does provide NO and NO_2

O_3 and NO+NO_2 annual average anomalies shown 4-times per year.

Sunset ———

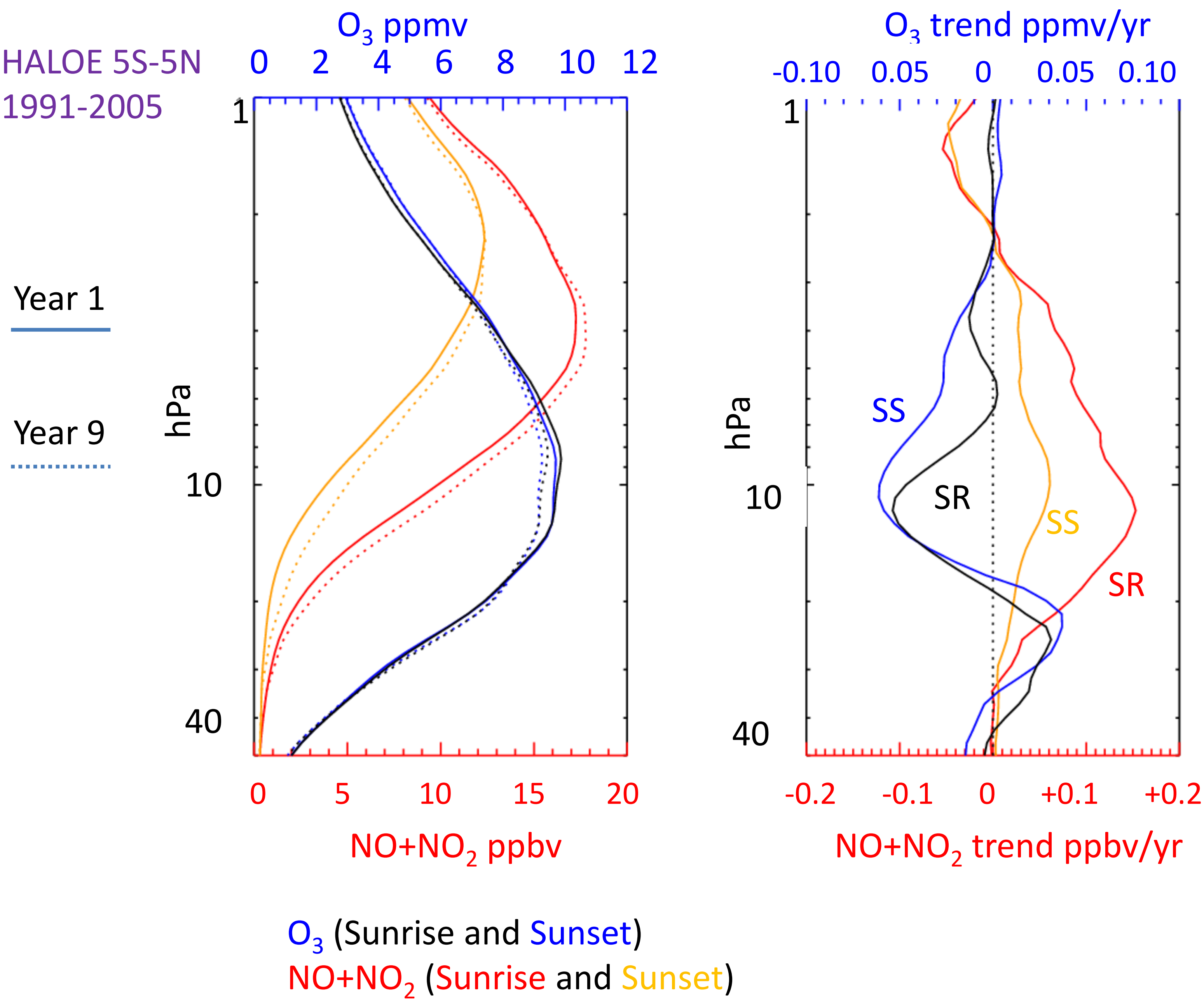
Sunrise -------

HALOE NO+NO_2



NO+NO_2 vs. O_3 shows a strong anti-correlation over long timescales.

Vertical profiles of tropical O_3 and NOx changes from linear trends



How does Age-of-Air change?
Simulating changes in tropical upwelling.

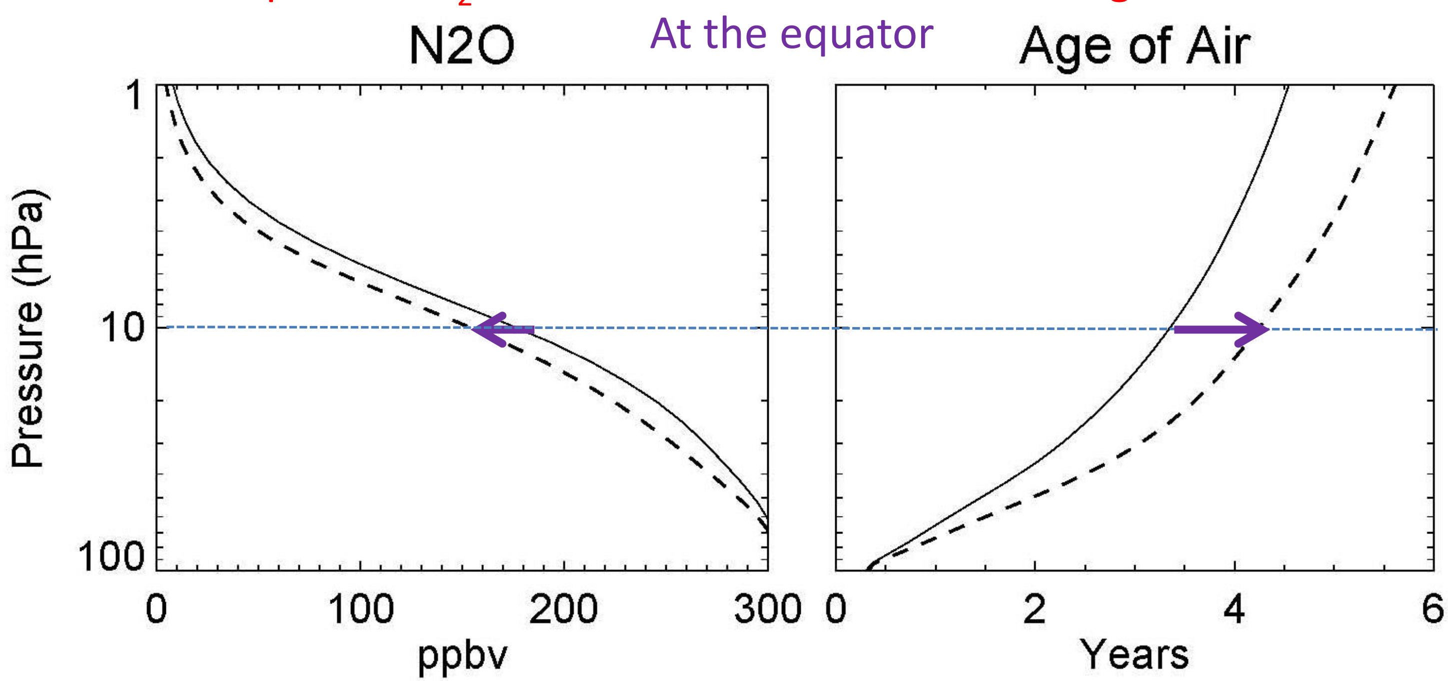
Need to compare model with fast upwelling (young) and slow upwelling (old)

Use simple 2D model (Bacmeister et al., 1998)

1) Baseline model (dashed)
2) Younger model (Added a 0.3K/day heat source at 18km at equator, solid).

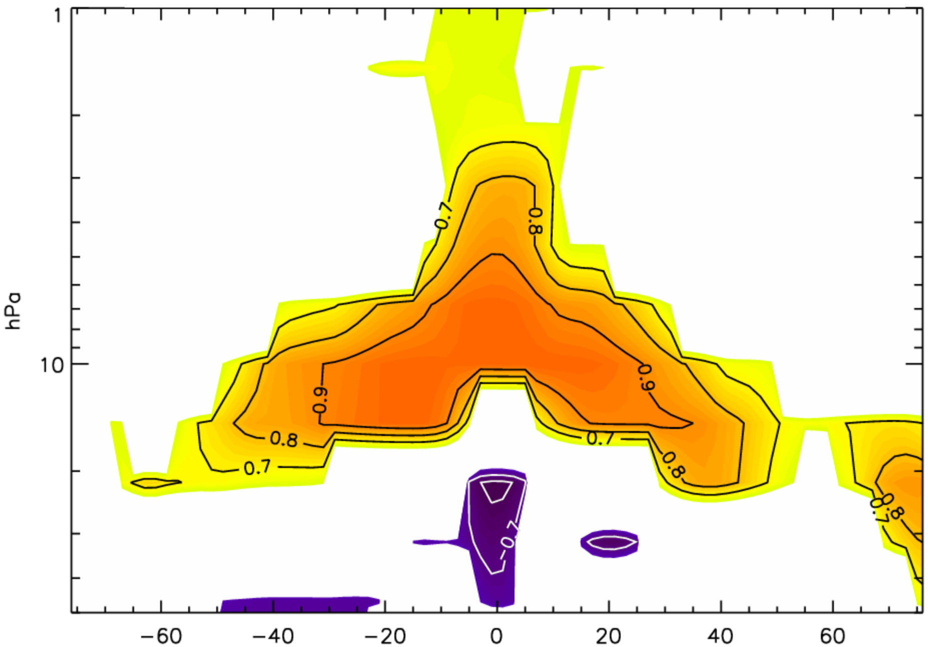
Older air has lower N_2O abundance at a given pressure.

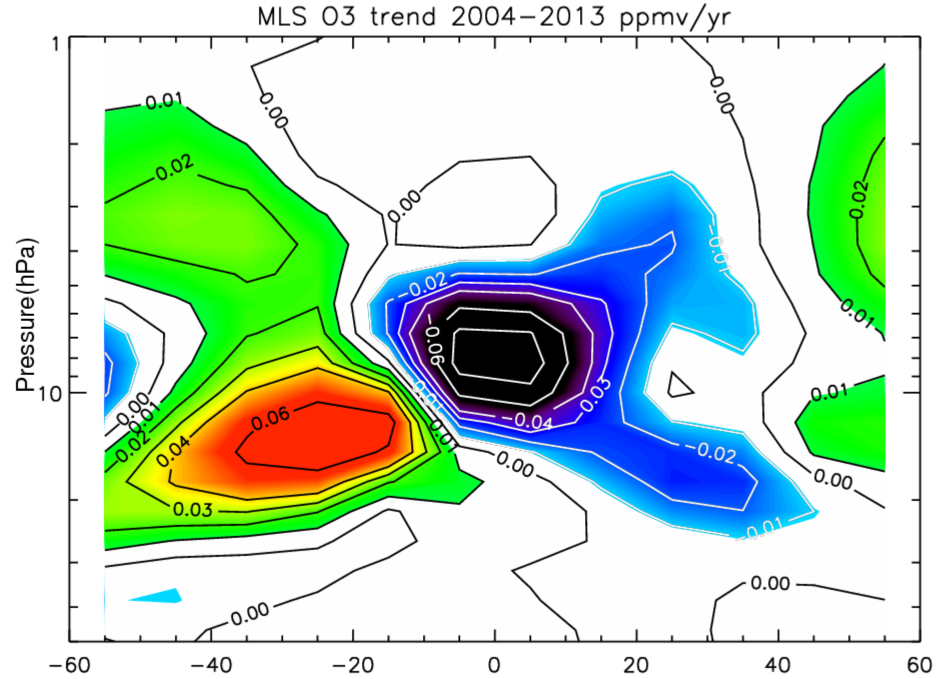
Requires a large change (>9 months) in Age-of-Air to perturb N_2O to match 2004-2013 MLS change



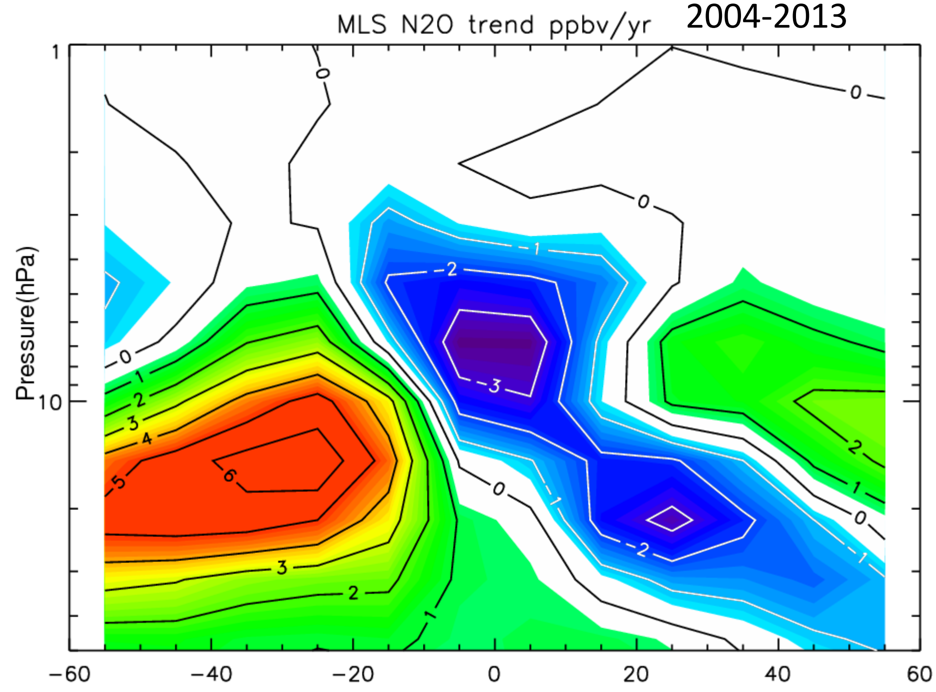
What about outside the tropics?

N_2O-O_3 monthly anomaly correlation





2004-2013



N_2O and O_3 trends from MLS since 2004 suggest:

- Older air at 10 hPa at equator
- Younger air in Southern Hemisphere between 20 hPa and 10 hPa

No such signature of younger air in HALOE O_3 (1991-2005)

MLS together with Ground-Based Microwave O_3 2004-2013

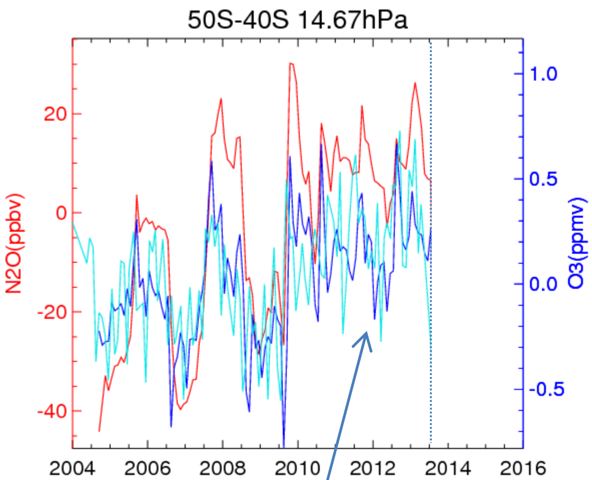
MLS O_3

MOPI (Microwave O_3 Profiling Instruments) at NDACC Lauder and Mauna Loa sites

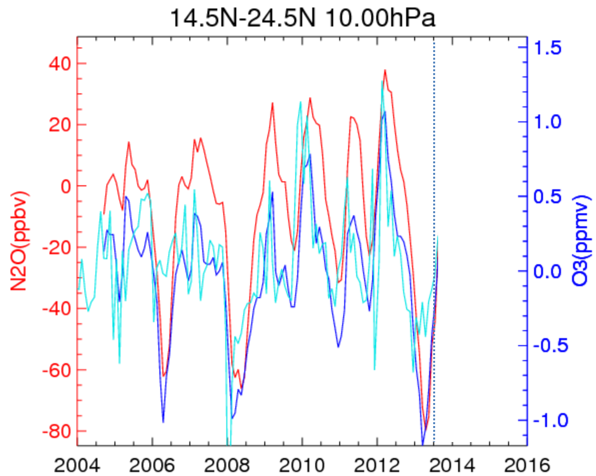
MLS N_2O

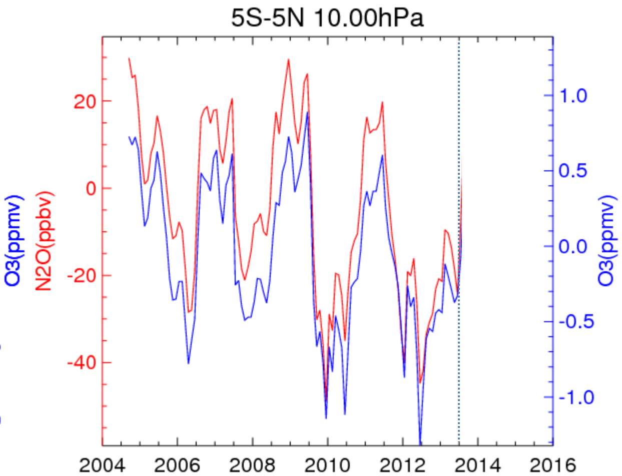
N_2O and O_3, especially in the tropics, show a strong correlation at ~10 hPa.

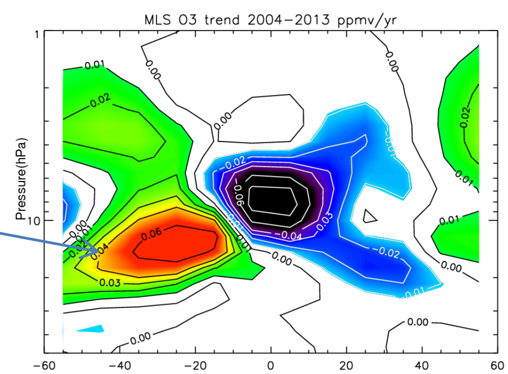
Lauder (45S)



Mauna Loa (19.5N)







~4 years of increased N_2O and O_3 over Lauder

Now add July 2013-present

MLS O_3

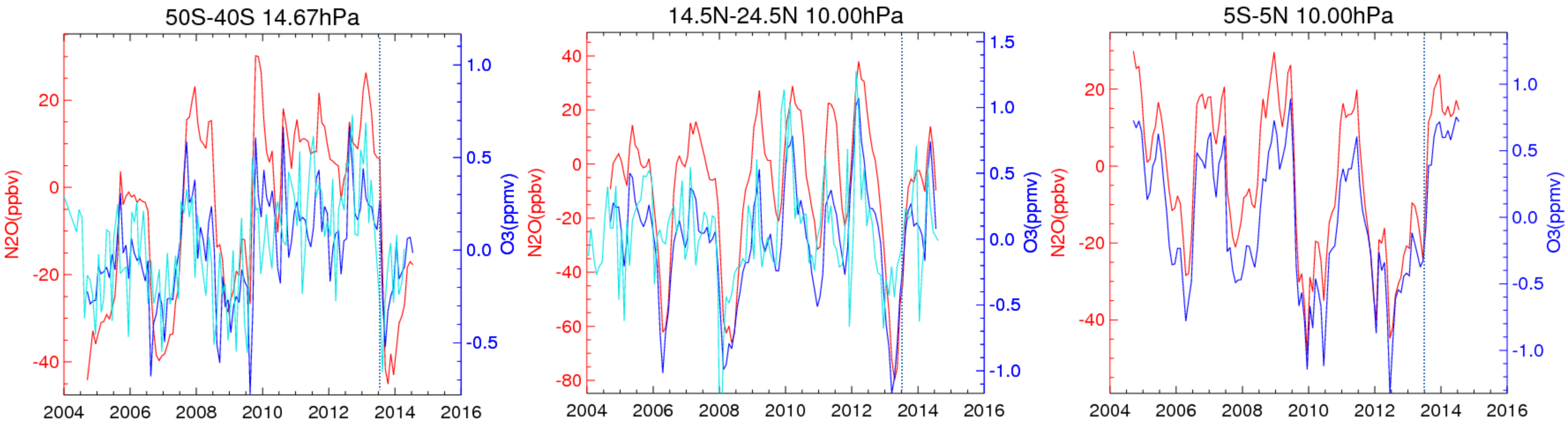
MOPI (Microwave O_3 Profiling Instruments) at NDACC Lauder and Mauna Loa sites

MLS N_2O

N_2O and O_3, especially in the tropics, show a strong correlation at ~10 hPa.

Lauder

Mauna Loa



- After the recent increase, tropical N_2O and O_3 values are now similar to those measured when Aura was launched
- Is this just a 1-year anomaly, or the sign of a reversal in a 20-year trend?

Summary

- Previously reported tropical ozone decreases at 10 hPa shown to extend over 20 years (1991-2013).

- Decrease in O_3 coincides with large decrease in N_2O (MLS) **and** large increase in NOx (HALOE). NOx is anticorrelated with N_2O.

- Likeliest explanation is **dynamical**. Slower upwelling leads to
  Decreased N_2O
  Increased NOx
  Decreased O_3

- Estimated Age-of-Air change in the tropics near ~10 hPa required to change N_2O by 20% is large → **> 9 months**. HALOE data implies even greater changes back to 1991!

- Other issues:
  1) MLS SH mid-lat N_2O and O_3 show opposite behavior from tropics
  2) Tropical mid-stratospheric N_2O and O_3 show a large increase since mid-2013, and are now similar to when Aura was launched in 2004